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Coronal Abundances and Thermal Structure of the X-ray Bright Hyades Giants

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Final Report

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Principal Investigator:

Robert A. Stern
Dept H1-12 Bldg 252
Solar and Astrophysics Laboratory
Lockheed Martin ATC
3251 Hanover St.
Palo Alto, CA 94304
(415) 424-3272

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1. Summary

The Hyades star θ^1 Tau is one of four K0 III giants in this nearby (d$\sim$45pc) open cluster. It is also one of the brightest coronal X-ray sources in the Hyades, with $L_X \approx 10^{30}$ erg s^{-1}. Because of the known photospheric composition and age of the Hyades, θ^1 Tau is an excellent candidate to study the relationship between stellar activity and coronal abundances. ROSAT observed θ^1 Tau during the All Sky Survey, and in a long (17 ksec) pointed observation in September 1992. When ASCA observed θ^1 Tau for $\sim$ 30 ksec in September 1995, its X-ray brightness had not significantly changed. We present the ASCA X-ray spectrum, and examine models of θ^1 Tau consistent with both the ASCA and ROSAT spectra.

2. Technical Progress

2.1 Introduction

Among the stars in the nearby (45 pc) Hyades cluster are four K0 III "clump" giants, helium burning stars of $\gtrsim 2.2\ M_\odot$. They all exhibit chromospheric and coronal activity (Stern, Schmitt, and Kahabka 1995). Residing in the "clump" region of the H-R diagram, the Hyades giants also lie near the coronal "dividing line" separating stars with strong and weak (or no) X-ray emission (see Haisch *et al.* 1991 and references therein). At present, the only other example of such a "clump" giant observed both by ASCA and EUVE is the nearby star β Cet (Drake *et al.* 1994, Ayres *et al.* 1995). A major unresolved question is whether the coronal temperature structure and abundance pattern displayed by this star is typical, or if there is a wide variation among the giants themselves. The X-ray bright Hyades giants are an excellent choice for a comparison because of their known age, proximity (45 pc), composition, and X-ray luminosity ($\sim 10^{30}$ erg s^{-1}). The metallicity for the Hyades giants is log [Fe/H]=+0.15 compared to the Sun, and C and O are under-abundant by about 0.4 dex (Lambert and Ries 1981, Cayrel *et al.* 1985, Griffin and Holweger 1989). Finally, β Cet and θ^1 Tau are related to the more famous active binary system, Capella, consisting of a G8 III primary similar to θ^1 Tau, and a rapidly rotating G0 III secondary. Capella exhibits a "bump" in its emission measure distribution at log T $\sim$ 6.8 (Dupree *et al.* 1993). Ayres and Brown (1994) have suggested that this arises primarily from the G8 III primary. If θ^1 Tau exhibits an EM distribution with such a "bump", this would be strong evidence for the composite hypothesis.

2.2 Observations

θ^1 Tau was observed by ASCA from 1344 UT 18 September to 0751 UT 19 September 1995 for a total exposure time of $\approx$ 30 ksec. The count rate in the SIS0 detector was $\sim$ 0.17 counts/sec. An earlier ROSAT PSPC observation of θ^1 Tau was performed in

September 1992. EUVE observed θ^1 Tau for a total of $\approx$ 165 ksec net exposure during the period 21 January to 1 February 1996.

2.3 Results

Short and Long Term Variability

Unlike the very active RS CVn systems, θ^1 Tau exhibits no strong X-ray variability on short or long time scales: the observed SIS count rate is nearly exactly that predicted using the ROSAT PSPC data taken 3 years earlier, and there are no obvious flares (see Figure 1). Earlier ROSAT all sky survey data demonstrated that θ^1 Tau had increased in X-ray luminosity by no more than $\sim$ 50% over the course of a decade (Stern, Schmitt, and Kahabka 1995).

Temperature Distribution and Abundances

The combined ASCA SIS, GIS and ROSAT data are not adequately fit using a single temperature, solar abundance model (MEKAL or MEKA). Adding a second component improves the fit, but only in the region below 0.5 keV, where only the PSPC is sensitive. However, unlike the case of many active binary systems (e.g. White *et al.* 1994, Antunes *et al.* 1994, Stern *et al.* 1995), which require low ($\sim$1/3) Fe abundances, the ASCA fit is improved in the case of θ^1 Tau by allowing the Mg abundance to increase by about a factor of 2 (Mg/H = 1.86$\pm$0.25, 90% L.O.C. 1 parameter). Allowing the other elemental abundances to vary seems to have little effect; slight improvements in the fit are gained with a near-zero Ne abundance. The overall fit is shown in Figure 2 (SIS: dark crosses, GIS: light crosses, PSPC: dark crosses, lower curve). Note that the contributions to χ^2 are largely from the SIS data. We have also fit the spectrum to about the same level using a (corrected) Chebyshev polynomial model of the emission measure (EM) distribution (Figure 3). In this case, Mg/H $\sim$ 1.6, showing the systematic effect of changing the temperature distribution.

2.4 Conclusions

θ^1 Tau, unlike more active RS CVn systems, has a fairly narrow temperature distribution, peaked at log T $\sim$ 6.8 (as evidenced by both the ASCA data and a later EUVE observation). As with β Cet, the Mg/H abundance is enhanced, perhaps by as much as a factor of 2. θ^1 Tau exhibits little of the short term variability seen in active stars, and is relatively constant in X-ray luminosity over several years.

3. Presentations and Publications

An earlier version of this work was presented at the ASCA 3rd Anniversary Syamposium: "X-ray Imaging and Spectroscopy of Cosmic Hot Plasmas - International Symposium

on X-ray Astronomy", March 11-14, 1996, Tokyo, Japan. A paper contribution will be including in the proceedings of this conference, to be published by the Universal Academy Press, Japan.

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REFERENCES

Antunes, A., Nagase, F., and White, N.E., 1994, ApJ, 436, L83.

Ayres, T., and Brown, A., 1994, BAAS, 26, 863.

Ayres, T., *et al.* , 1995, BAAS, 26, 1381.

Cayrel, R., Cayrel de Strobel, G., Campbell, B., 1985, A&A, 146, 249.

Drake, S.A., Singh, K.P, White, N.E., and Simon, T., 1994S, ApJ, accepted.

Dupree, A.K., Brickhouse, N.S., Doscheck, G.A., Green, J.C., Raymond, J.C., 1993 , ApJ, 418, L41.

Griffin, R.E.M., and Holweger, H., 1989, A&A, 214, 249.

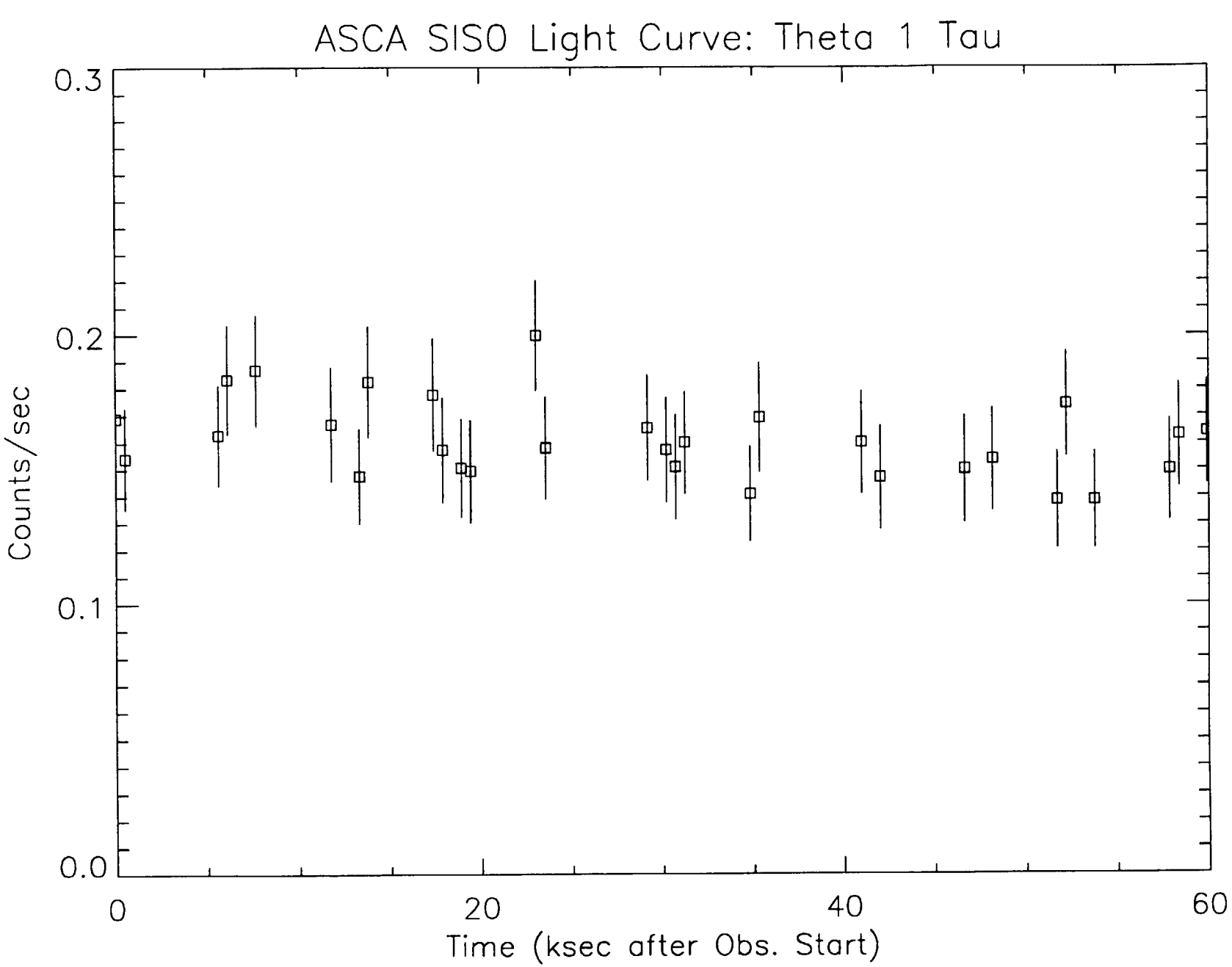
Haisch, B.M., Schmitt, J.H.H.M, and Rosso, C., 1991, ApJ, 383, L15.

Lambert, D.L, and Ries, L.M., 1981, ApJ, 248, 228.

Stern, R.A., Lemen, J.R., Pye, J.P., and Schmitt, J.H.M.M., 1995, ApJ, 444, L45.

Stern, R.A., Schmitt, J.H.M.M., and Kahabka, 1995, ApJ, 448, 683.

White, N.E., *et al.* , 1994, PASJ, 46, L97.


ASCA SIS0 Light Curve: Theta 1 Tau
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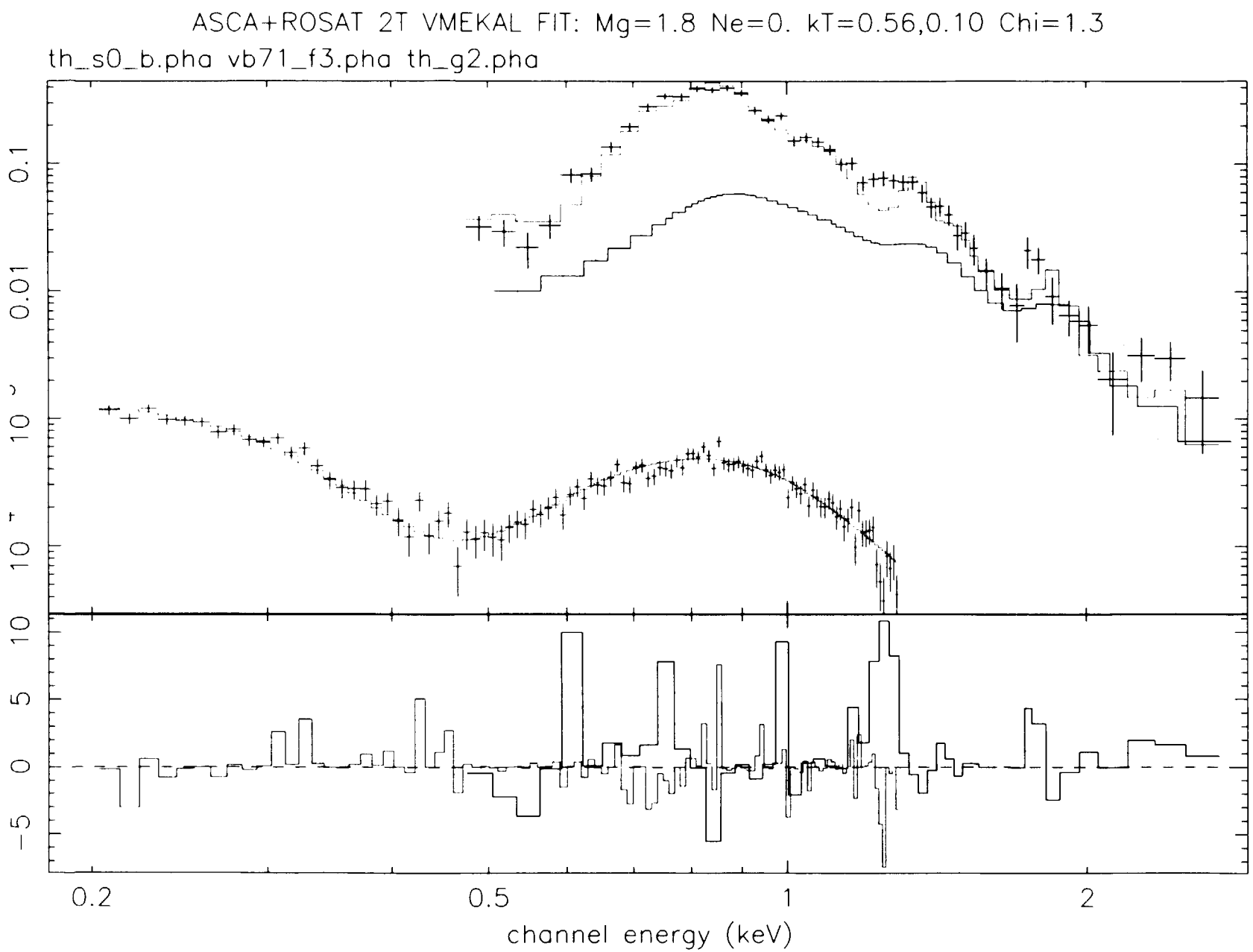
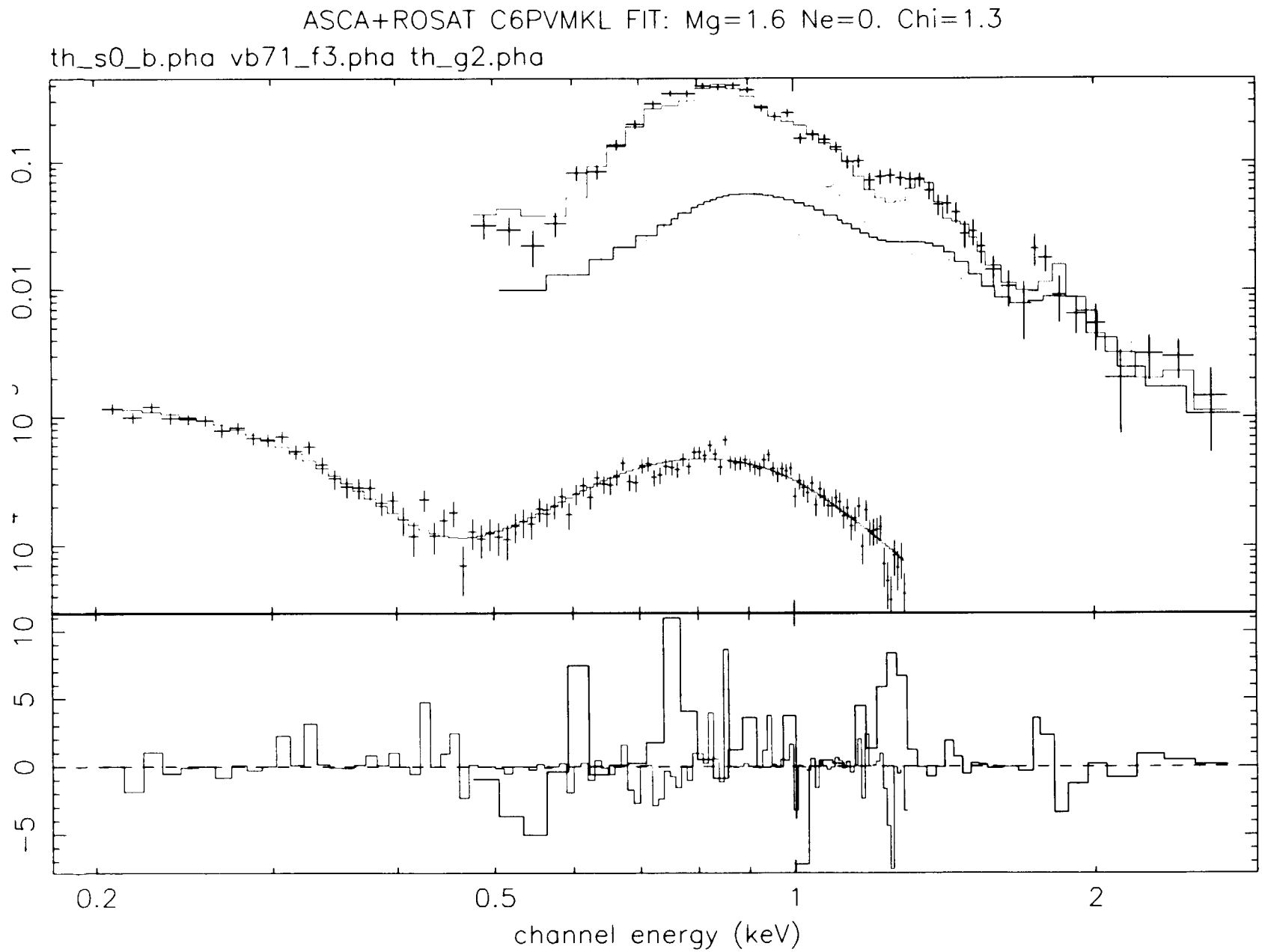
0.2
0.1
0.0
Counts/sec
0
20
40
60
Time (ksec after Obs. Start)


ASCA+ROSAT 2T VMEKAL FIT: Mg=1.8 Ne=0. kT=0.56,0.10 Chi=1.3
th_s0_b.pha vb71_f3.pha th_g2.pha
0.1
0.01
10 ⁻
10 ⁻
10
5
0
−5
0.2
0.5
1
2
channel energy (keV)

stern 6-Ma


ASCA+ROSAT C6PVMKL FIT: Mg=1.6 Ne=0. Chi=1.3
th_s0_b.pha vb71_f3.pha th_g2.pha
0.1
0.01
10 ⁻
10 ⁻
10
5
0
-5
0.2
0.5
1
2
channel energy (keV)

stern 6-Mai